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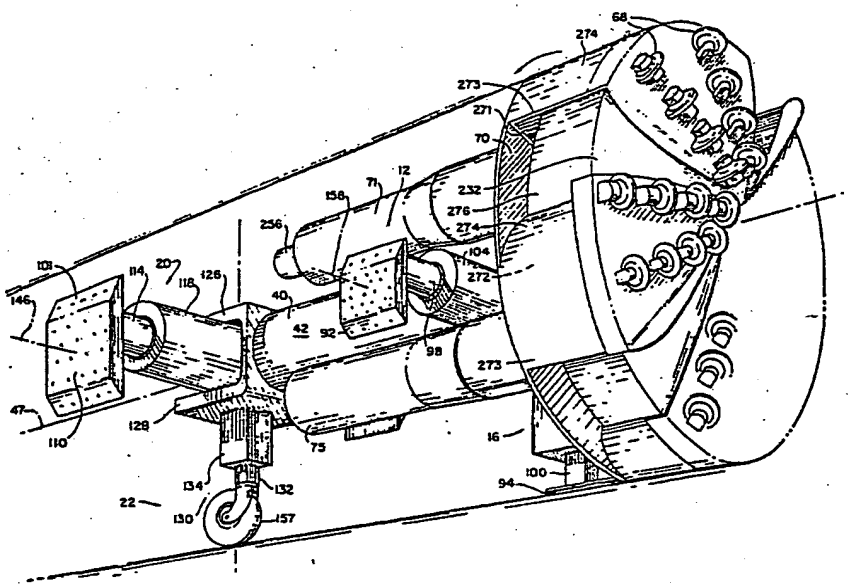
(57) Abstract

A tunnel boring machine for controlled boring of an elongated curvilinear tunnel in earth strata. The tunnel boring machine comprises: cutting means (66) for engaging the tunnel face and removing material therefrom to elongate the tunnel during a outting stroke; elongated body means (40) for supporting various machine components; elongate thrust arm means (42) for urging the cutting means against the tunnel face and for advancing the elongated body means along the tunnel between cutting strokes, the thrust arm means being extendable and retractable from the body means along a thrust arm axis coaxial a machine longitudinal axis, forward lateral positioning means (12,14) operably mounted on a forward portion of the body means for selectively controlling the lateral positioning of a forward portion of the body means within the tunnel; rear lateral positioning means (18, 20) operably mounted on a rear portion of the body means; forward transverse positioning means (16) operably mounted on a forward portion of the body means for selectively controlling the transverse positioning of a forward portion of the body means within the tunnel; rear transverse positioning means (22) operably mounted on a rear portion of the body means for selectively controlling the transverse positioning of the body means within the tunnel; and tunnel gripping means (90, 92, 94) operably mounted on the body means. Various methods of operation of the machine are described.



CLAIMS

1. A tunnel boring machine for controlled boring of an elongated curvilinear tunnel in earthen strata, the tunnel having a central longitudinal axis, and having tunnel cross sections perpendicular to the central longitudinal axis, the tunnel cross sections having a lateral axis oriented generally perpendicular to the direction of gravitational force and intersecting the central longitudinal axis and having a transverse axis intersecting the central longitudinal axis and the lateral axis and perpendicular to both, the tunnel having an end face and peripheral side wall, the tunnel boring machine comprising:

cutting means for engaging the tunnel face and removing material therefrom to elongate the tunnel during a cutting stroke;

elongated body means for supporting various machine components having a forward end positioned proximal the tunnel face and a rear end positioned distal the tunnel face and defining a central longitudinal machine axis extending between said forward end and said rear end;

elongate thrust arm means for urging said cutting means against the tunnel face during a cutting stroke and for advancing said elongated body means forwardly along the tunnel toward said cutting means between cutting strokes, said thrust arm means being extendable and retractable relative to said body means along said longitudinal machine axis;

forward positioning means operably mounted on a forward portion of said body means for selectively positioning a forward portion of the body means within the tunnel;

rear positioning means operably mounted on a rear portion of said body means for selectively

positioning a rear portion of said body means within the tunnel;

whereby the longitudinal machine axis of said body means is selectively positionable relative the longitudinal axis of the tunnel through the use of said forward and rear positioning means; and

tunnel gripping means operably mounted on said body means for selectively grippingly engaging the peripheral sidewall of said tunnel whereby axial rearward movement of said body relative the tunnel sidewall means during a cutting stroke is prevented.

2. The invention of claim 1 wherein said cutting means comprises:

rotatable cutting wheel means operably mounted on said thrust arm means, said cutting wheel means having an axis of rotation coaxial with said thrust arm means; and

cutting wheel drive means operably associated with said cutting wheel means for rotating said cutting wheel means about said axis of rotation.

3. The invention of claim 1 or 2 wherein said cutter wheel means comprises a convex dome shaped forward surface having rolling cutter devices mounted thereon.

4. The invention of claim 1, 2 or 3 wherein said forward positioning means comprises:

forward lateral positioning means for selectively positioning a forward portion of the body means in a lateral direction; and

forward transverse positioning means for selectively positioning a forward portion of the body means in a transverse direction and said rear positioning means comprises:

rear lateral positioning means for selectively poisitioning a rear portion of said body means in a lateral direction; and

rear transverse positioning means for selectively positioning a rear portion of said body means in a transverse direction.

5. The invention of claim 4 wherein said rear lateral positioning means comprises opposite extendable and retractable rear arm means for selective engagement and disengagement with the tunnel sidewall said opposite rear arm means being coaxial with a rear arm axis intersecting said longitudinal machine axis of and angularly displaceable with respect thereto about a rear transverse axis, said rear transverse axis, said rear arm axis and said machine longitudinal axis intersecting at and defining a rear machine pivot point.

6. The invention of claim 5 wherein said opposite rear arm means comprise:

opposed rear lateral cylinder means privotally mounted on said body means in coaxial relationship with said rear arm axis and pivotal about said rear transverse axis;

opposed extendable and retractable rear piston means operably mounted in associated rear lateral cylinder means; and

rear gripping pad means universally swivelly mounted at the ends of associated rear piston means for grippingly engaging the tunnel wall.

7. The invention of claim 6 further comprising rear cylinder adjusting means for pivoting said rear cylinder means about said rear transverse axis for aligning said rear cylinder means in perpendicular relationship with the tunnel longitudinal axis.

8. The invention of claim 6 wherein said rear transverse positioning means comprises extendable and retractable support wheel means said support wheel means being extendable and retractable along said transverse rear axis and being capable of rollingly supporting a rear end portion of said body means.

9. The invention of any one of claims 4 to 8 wherein said forward lateral positioning means comprises opposite laterally extendable and retractable forward arm means for selective engagement and disengagement with the tunnel sidewall said opposite front arm means being coaxial with a forward arm axis intersecting said longitudinal machine axis and substantially perpendicular thereto.

10. The invention of claim 9 wherein said opposite forward arm means comprise:

opposed forward lateral cylinder means fixedly mounted on said body means and coaxial with said forward arm axis;

opposed extendable and retractable forward piston means operably mounted in associated forward lateral cylinder means; and

forward gripping pad means universally swivelly mounted at the ends of associated forward piston means for grippingly or slidingly engaging the tunnel wall.

11. The invention of claim 10 wherein said forward transverse positioning means comprises:

a forward transverse cylinder means fixedly attached to said body means and coaxially aligned with a forward transverse axis intersecting said longitudinal axis and perpendicular thereto;

extendable and retractable forward transverse piston means operably mounted in said forward transverse cylinder means; and

base plate means for supportingly engaging the tunnel floor, said base plate means being swivelly mounted on said forward transverse piston means for angularly displaceable movement relative thereto and having lateral slide means for allowing laterally shifting movement of said forward transverse piston

means relative a floor engaging portion of said base plate means.

12. The invention of claim 4 wherein said rear transverse positioning means comprises extendable and retractable rear transverse leg means for selective rolling supportable engagement with the tunnel floor.

13. The invention of claim 12 wherein said forward transverse positioning means comprises extendable and retractable forward leg means for supporting engagement with said tunnel floor.

14. The invention of claim 13 wherein:

said rear arm means comprise rear arm control means for extending said rear arm means into tunnel wall gripping contact at the beginning of a cutting stroke and for retracting said rear arm means at the end of a cutting stroke in straight ahead, horizontally curved, or vertically curved modes of operation; wherein said rear arm control means further comprises adjusting means for pivoting said rear arm means axis into perpendicular relationship with the tunnel longitudinal axis;

and wherein said rear leg means comprises rear leg control means for retracting said rear leg means prior to the beginning of a cutting stroke and for extending said rear leg means after the completion of a cutting stroke to support the rear end of said body means during forward movement thereof between cutting strokes in straight ahead, horizontally curved or vertically curved modes of operation;

and wherein said forward arm means comprises forward arm control means for extending said forward arm means into wall gripping contact at the beginning of a cutting stroke and retracting said forward arm means at the end of a cutting in a straight ahead mode of operation, and for placing

said forward arm means into continuous steering contact with the tunnel wall wherein one portion of said forward arm means is continuously extended during a cutting stroke and an opposite portion of said forward arm means is continously retracted during said cutting stroke and for retracting said forward arm means from wall engaging contact at the end of said cutting stroke in the horizontally curved cutting mode of operation, and for extending said forward arm means into equally extended sliding contact with the tunnel wall during a cutting stroke and for retracting said forward arm means from sliding contact with the tunnel wall at the end of said cutting stroke in a vertically curved mode of operation;

and wherein said forward leg means comprises forward leg control means for retracting said forward leg means at the end of a cutting stroke to place said cutting wheel means in self supporting engagement with the tunnel side wall and for extending said forward leg means to raise the cutting wheel means into transverse alignment with the longitudinal axis of the tunnel and to retain it in transverse alignment with the tunnel longitudinal axis during the cutting stroke in straight ahead and horizontally curved modes of operation and to continuously transversely raise or lower the cutting wheel relative the tunnel longitudinal axis during the cutting stroke in the vertically curved mode of operation;

and wherein said thrust arm means comprises thrust arm control means for extending said thrust arm relative said body means for advancing said cutting wheel means during a cutting stroke and for retracting said thrust arm means relative said body

means for advancing said body means between cutting strokes.

15. A method for boring an elongated tunnel having a central longitudinal axis and having tunnel cross-sections each having a lateral axis oriented generally perpendicular to the direction of gravitational force and intersecting the central longitudinal axis and having a transverse axis intersecting the central longitudinal axis and the lateral axis and perpendicular to both wherein the steps comprise:

(a) providing a tunnel boring machine having an elongated main body with an elongated thrust arm extendably and retractably mounted therein and moveable along a machine longitudinal axis, and having a rotatable cutter wheel mounted at the free end of the elongated thrust arm, and having forward lateral and forward transverse positioning devices and having rear lateral and rear transverse positioning devices;

(b) positioning a rear machine pivot point of the main body lying on the machine longitudinal axis at a point on the tunnel longitudinal axis through the use of the rear lateral and rear transverse positioning devices;

(c) fixing the rear pivot point in linearly nondisplaceable relationship with respect to the tunnel longitudinal axis by extending the rear lateral positioning means into wall gripping contact;

(d) retracting the rear transverse positioning device to a noninterfering position relative the tunnel surface;

(e) positioning a forward point on the machine longitudinal axis at a predetermined position within the tunnel by the use of the forward lateral and

forward transverse positioning means;

(f) fixing said forward machine point in linearly nondisplaceable relationship with respect to the tunnel wall by grippingly engaging the tunnel wall with the forward lateral and forward transverse positioning devices;

(g) placing the cutting means in engaging contact with the tunnel face by extension of the elongated thrust arm during a cutting stroke from a retracted start of stroke position to an extended end of stroke position;

(h) disengaging the forward lateral positioning means from gripping engagement with the tunnel wall;

(i) lowering the cutting wheel onto the tunnel floor by retraction of the forward transverse positioning device;

(j) extending the rear transverse positioning device to support a rear portion of the main body;

(k) disengaging the rear lateral positioning device from gripping engagement with the tunnel wall;

(l) moving the main body in a forwardly direction by retraction of the thrust arm; and

(m) repeating steps a through l until a tunnel straight line portion is completed.

16. A method for boring an elongated curved tunnel having a central longitudinal axis and having tunnel cross-sections each having a lateral axis oriented generally perpendicular to the direction of gravatation force and intersecting the central longitudinal axis and having a transverse axis intersecting the central longitudinal axis and the lateral axis and perpendicular to both wherein the steps comprise:

(a) providing a tunnel boring machine having an elongated main body with an elongated thrust arm

extendably and retractably mounted therein and moveable along a machine longitudinal axis, and having a rotatable cutter wheel mounted at the free end of the elongated thrust arm, and having forward lateral and forward transverse positioning devices and having rear lateral and rear transverse positioning devices;

(b) positioning a rear machine pivot point of the main body lying on the machine longitudinal axis at a point on the tunnel longitudinal axis through the use of the rear lateral and rear transverse positioning devices;

(c) fixing the rear pivot point in linearly nondisplaceable relationship with respect to the tunnel longitudinal axis by extending the rear lateral positioning means into wall gripping contact;

(d) retracting the rear transverse positioning device to a noninterfering position relating the tunnel surface;

(e) positioning a forward point on the machine longitudinal axis at a predetermined position within the tunnel by the use of the forward lateral and forward transverse positioning means;

(f) placing the cutting means in engaging contact with the tunnel face by extension of the elongated thrust arm during a cutting stroke from a retracted start of stroke position to an extended end of stroke position;

(g) simultaneously with step f, pivoting the main body about the rear machine pivot point by use of at least one of the forward lateral positioning device and the forward transverse positioning device;

(h) lowering the cutting wheel onto the tunnel floor by retraction of the forward transverse positioning device;

(i) extending the rear transverse positioning device to support a rear portion of the main body;

(j) disengaging the rear lateral positioning device from gripping engagement with the tunnel wall;

(k) moving the main body in a forwardly direction by retraction of the thrust arm; and

(l) repeating steps a through k until a tunnel curved portion is completed.

17. A method for boring an elongated curvilinear tunnel having a central longitudinal axis and having tunnel cross-sections each having a lateral axis oriented generally perpendicular to the direction of gravitational force and intersecting the central longitudinal axis and having a transverse axis intersecting the central longitudinal axis and the lateral axis and perpendicular to both wherein the steps comprise:

(a) providing a tunnel boring machine having an elongated main body with an elongated thrust arm extendably and retractably mounted therein and moveable along a machine longitudinal axis, and having a rotatable cutter wheel mounted at the free end of the elongated thrust arm, and having forward lateral and forward transverse positioning devices and having rear lateral and rear transverse positioning devices;

(b) positioning a rear machine pivot point of the main body lying on the machine longitudinal axis at a point on the tunnel longitudinal axis through the use of the rear lateral and rear transverse positioning devices;

(c) fixing the rear pivot point in linearly nondisplaceable relationship with respect to the tunnel longitudinal axis by extending the rear lateral positioning means into wall gripping contact;

(d) retracting the rear transverse positioning device to a noninterfering position relative the tunnel surface;

(e) positioning a forward point on the machine longitudinal axis at a predetermined position within the tunnel by the use of the forward lateral and forward transverse positioning means;

(f) fixing said forward machine point in linearly nondisplaceable relationship with respect to the tunnel wall by grippingly engaging the tunnel wall with the forward lateral and forward transverse positioning devices;

(g) placing the cutting means in engaging contact with the tunnel face by extension of the elongated thrust arm during a cutting stroke from a retracted start of stroke position to an extended end of stroke position;

(h) disengaging the forward lateral positioning means from gripping engagement with the tunnel wall;

(i) stop rotation lowering the cutting wheel onto the tunnel floor by retraction of the forward transverse positioning device;

(j) extending the rear transverse positioning device to support a rear portion of the main body;

(k) disengaging the rear lateral positioning device from gripping engagement with the tunnel wall;

(l) moving the main body in a forwardly direction by retraction of the thrust arm; and

(m) repeating steps a through l until a tunnel straight line portion is completed.

(n) positioning a rear machine pivot point of the main body lying on the machine longitudinal axis at a point on the tunnel longitidunal axis through the use of the rear lateral and rear transverse positioning devices;

(o) fixing the rear pivot point in nondisplaceable relationship with respect to the tunnel longitudinal axis by extending the rear lateral positioning means into wall gripping contact;

(p) retracting the rear transverse positioning device to a noninterfering position relative the tunnel surface;

(q) positioning a forward point on the machine longitudinal axis at a predetermined position within the tunnel by the use of the forward lateral and forward transverse positioning means;

(r) placing the cutting means in engaging contact with the tunnel face by extension of the elongated thrust arm during a cutting stroke from a retracted start of stroke position to an extended end of stroke position;

(s) simultaneously with step f, pivoting the main body about the rear machine pivot point by use of at least one of the forward lateral positioning device and the forward transverse positioning device;

(t) lowering the cutting wheel onto the tunnel floor by retracting of the forward transverse positioning device;

(u) extending the rear transverse positioning device to support a rear portion of the main body;

(v) disengaging the rear lateral positioning device from gripping engagement with the tunnel wall;

(w) moving the main body in a forwardly direction by retraction of the thrust arm; and

(x) repeating steps n through w until a tunnel curved portion is completed.

(y) repeating steps a through x until the curvilinear tunnel is completed.

18. An elongated tunnel boring machine, having a central longitudinal machine axis, for boring a linear

tunnel section in a linear boring mode of operation or a curvilinear tunnel section in a curvilinear boring mode of operation; the tunnel having an end face and a peripheral side wall including a floor portion, a ceiling portion, and opposite side wall portions spaced from a central longitudinal tunnel axis; and the tunnel boring machine comprising:

rotatable cutting wheel means at the front end of the machine and having a central axis of rotation which is coaxial with the machine axis and adapted to be selectively located at a desired position approximately at the laterally opposite portion of the central longitudinal tunnel axis and held against the tunnel face during rotation for cutting material away from the tunnel face to elongate the tunnel and extend the central longitudinal tunnel axis in a selected direction;

motor means operatively connected to said rotatable cutting wheel means for selectively causing rotation thereof in a cutting mode of operation and stopping rotation thereof in a non-cutting mode of operation;

extendable and retractable thrust means, including a forwardly extending piston-rod means operably connected to said cutting wheel means and a rearwardly extending cylinder means operably supporting said forwardly extending piston-rod means, for selectively causing forward movement of said cutting wheel means against the tunnel face in the cutting mode of operation during a cutting stroke, said thrust means being selectively operable to cause forward relative axial movement between said piston-rod means and said cylinder means along the machine axis from a retracted position to an extended position to move the cutting wheel means

forwardly relative to said thrust means during a cutting stroke in the cutting mode of operation and from the extended position to the retracted position to move said thrust means forwardly relative to said cutting wheel means in the non-cutting mode to prepare the machine for the next cutting stroke;

extendable and retractable rear end clamping and positioning means for fixedly locating and holding the rear end portion of the machine between opposite tunnel side wall portions with the rear end portion of the central longitudinal machine axis located in approximately coaxial relationship with the laterally adjacent portion of the central longitudinal tunnel axis in the linear boring mode and with the rear end portion of the central longitudinal machine axis located in approximately intersecting relationship with the laterally adjacent portion of the central longitudinal tunnel axis in the curvilinear boring mode, and being selectively movable between outwardly extended engaging positions and inwardly retracted non-engaging positions relative to the tunnel wall to facilitate repositioning of the machine between cutting strokes;

pivotal connecting means between said rear end clamping and positioning means and the rear end portion of the machine to provide at least one pivotal axis which intersects the central longitudinal machine axis for enabling the central longitudinal machine axis to be laterally pivoted displaced relative to the central longitudinal axis about said pivotal axis during a cutting stroke in the curvilinear boring mode of operation; and

extendable and retractable front end clamping and positioning means for fixedly locating and

holding the front end portion of the machine between the opposite tunnel side wall portions with the central longitudinal machine axis located in approximately coaxial fixed relationship with the central longitudinal tunnel axis in the linear boring mode and for adjustably locating and holding the front end portion of the machine between opposite tunnel side wall portions during a cutting stroke with the central longitudinal machine axis in variably displaced laterally offset relationship with the central longitudinal tunnel axis of the last bored tunnel portion in the curvilinear boring mode by lateral pivotal displacement about said pivotal axis.